The investigation on the emission mechanism of InGaN/GaN quantum well structure

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Abstract

Although there are many reports on the optical investigation of InGaN/GaN quantum well structures, the emission mechanisms of this structure are still not fully understood. In this case, two different radiative recombination mechanisms are generally accepted. One is based on so-called localization effect, and another based on quantum confined Stark effect. Both mechanisms have a strong influence on the optical properties of InGaN/GaN-based devices. Therefore, it is necessary to study both of these effects. This paper investigates the quantum well thickness influence on the emission mechanism.

Temperature dependent photoluminescence (PL) measurements are performed on $In_{0.23}Ga_{0.77}N$/GaN single-quantum-well (SQW) structures with well thickness from 1.5nm to 5nm in each sample. The temperature dependent emission energy of each sample is plotted as a function of temperature as shown in Figure 1. In the case of 5nm SQW, the emission energy decreases monotonically with increasing temperature. For the other cases, the emission energy shows a temperature induced blue-shift at temperatures higher than around 65K, which is typical characteristic of localization effect. Based on the band tail model, the temperature-dependent emission energy in each sample is fitted, in which the σ value that indicates the localization effect[1] can is obtained as shown in Figure 1 (The solid lines correspond to the fitting curves using different σ values). In Figure 1, the σ value increases with increasing quantum well thickness up to 2.5nm, and then decreases, which indicates that the localization effect could be enhanced by increasing quantum well thickness if the quantum well thickness does not exceed 2.5nm. If the quantum well thickness is further increased to above 2.5nm, the localization effect became weak, finally, in the case of 5nm quantum well thickness, the localization effect can not be observed. To investigate the quantum confine Stark effect, the excitation-power dependent PL measurements are also carried out on these samples as shown in Figure 2. In the case of 1.5nm, the emission is almost independent of the excitation-power. However, with increasing the quantum well thickness, the large-pumping induced blue-shift shows much stronger, which means that the quantum confine Stark effect can be ignored in the thin quantum well structure and dominates the radiative recombination in the thick quantum well structure. The PL emission intensity is also measured as a function of the quantum well thickness, which indicates that the PL emission intensity decreases monotonically with increasing well thickness as shown in Figure 3. In connection with excitation-power dependent PL measurements, the result of PL emission intensity related to quantum well thickness could be attributed to quantum confine Stark effect.

Therefore, based on above results, the emission mechanism is dominated by localization effect in the thin quantum well structure, while the quantum confine Stark effect dominates the radiative recombination in the thick quantum well structure. Since the localization effect is generally accepted to play an important in lasing process of InGaN/GaN system and the high quantum efficiency is critically important for the fabrication of high brightness LED, our result should be highly emphasized in designing InGaN/GaN based optical devices.

References:

1. P.G. Eliseev, et al, Appl. Phys. Lett. 71, 569 (1997)

Figure 1

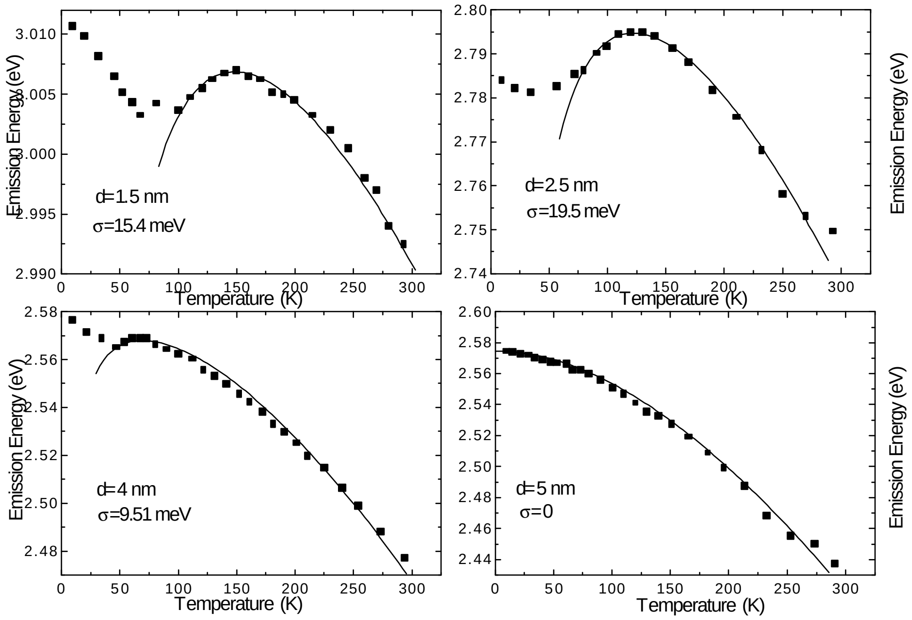

Figure 2

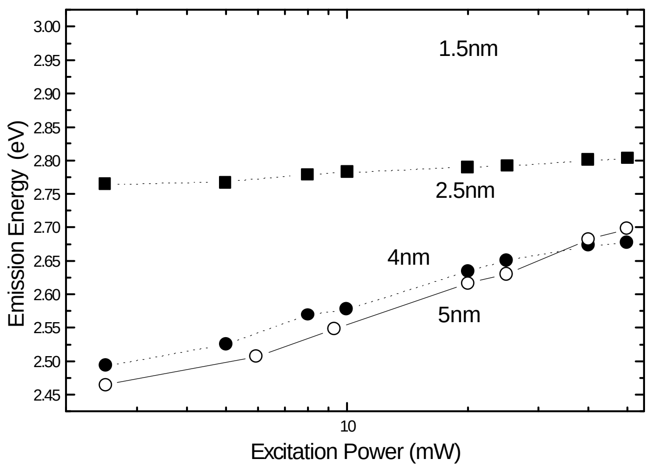

Figure 3